Towards the development of advanced TIMES demo models for electric vehicles

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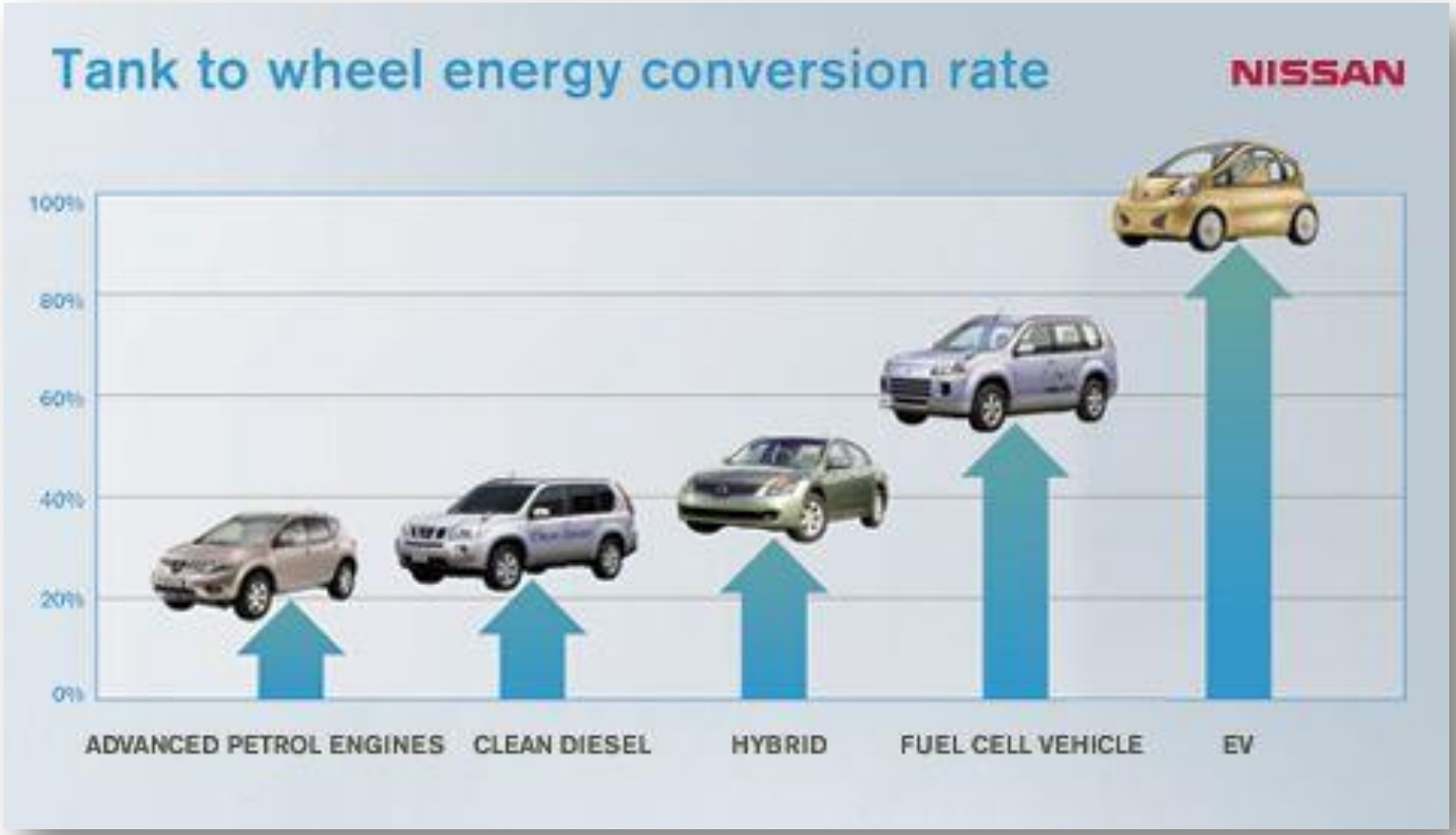
EFDA-TIMES and ETSAP-TIAM Workshop
DTU Risø Campus, Roskilde, Denmark
back-to-back with
64th Semi-annual ETSAP meeting, Seoul, Republic of Korea
Program continuing in Denmark with Skype connection to remote participants
5th November 2013

DeustoTech Energy

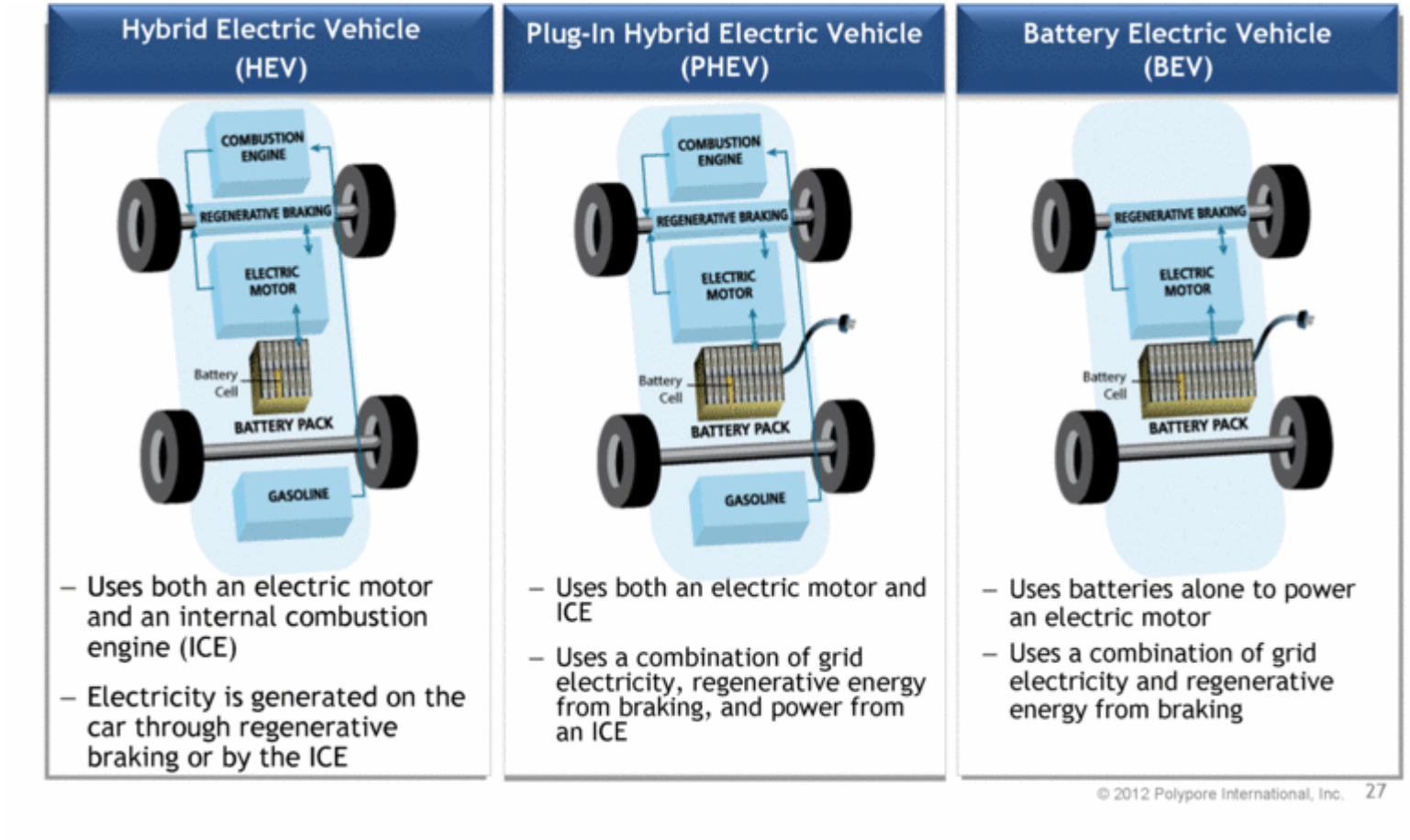
DTU Technical University of Denmark

Efficiency of vehicle technologies



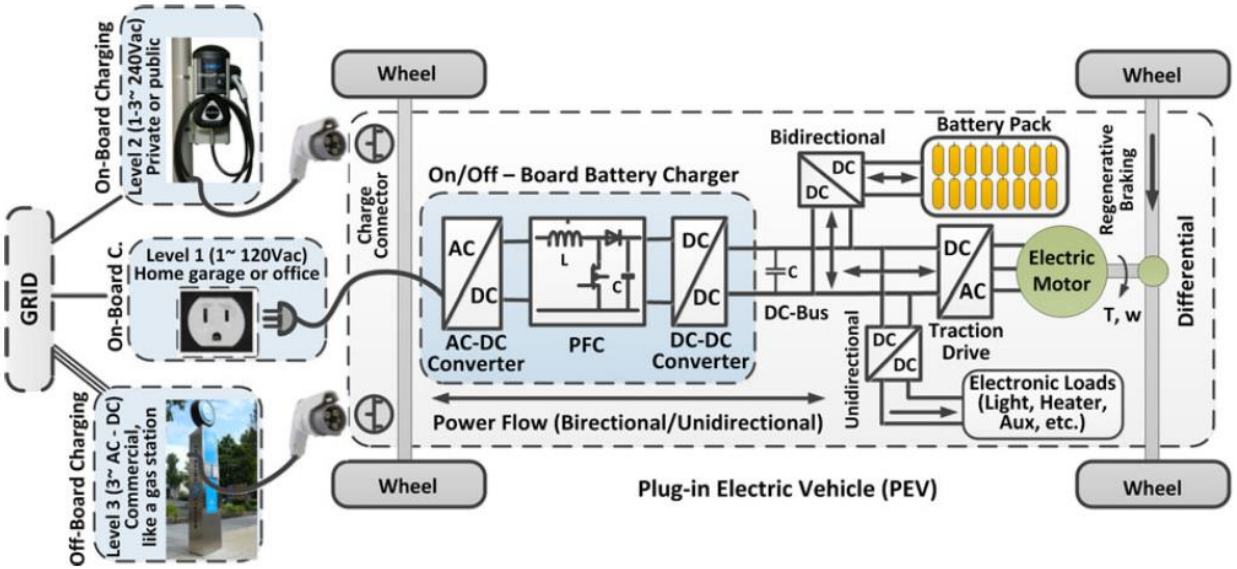
Source:
http://www.nissan.co.uk/GB/en/inside-nissan/news/leaf_news/ev-programme.html

Differences of electric driving vehicles (EDVs)



Source:
http://www.sec.gov/Archives/edgar/data/1292556/000110465912062939/g208032mmi027.gif

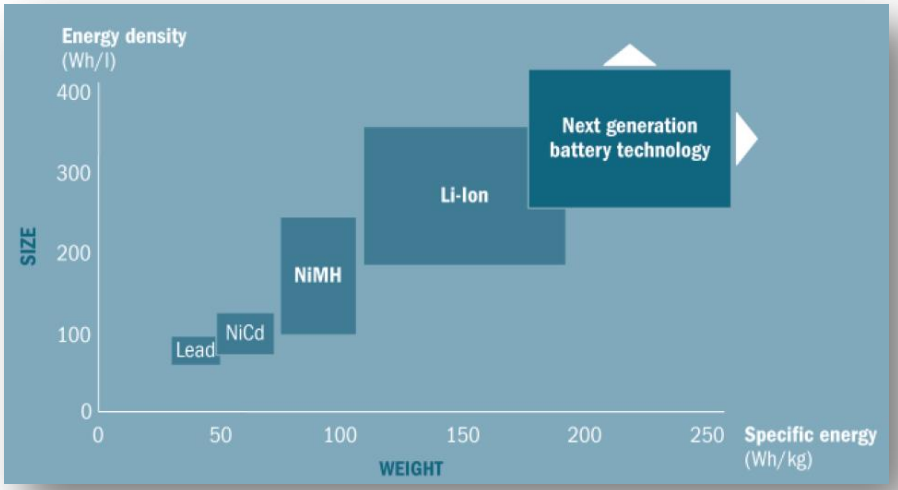
Infrastructure and power levels for charging PEVs



Recharging type	Power (kW)	Voltage - Current	Current type	Recharging time
Conventional recharging (slow)	up to 3.7	230 V - 16 A	AC	6 h - 8 h
Semi-fast recharging	up to 43	400 V - up to 62 A	AC	1.5 h - 4 h
Fast recharging	up to 100	400 V - up to 250 A	DC	15 min - 30 min

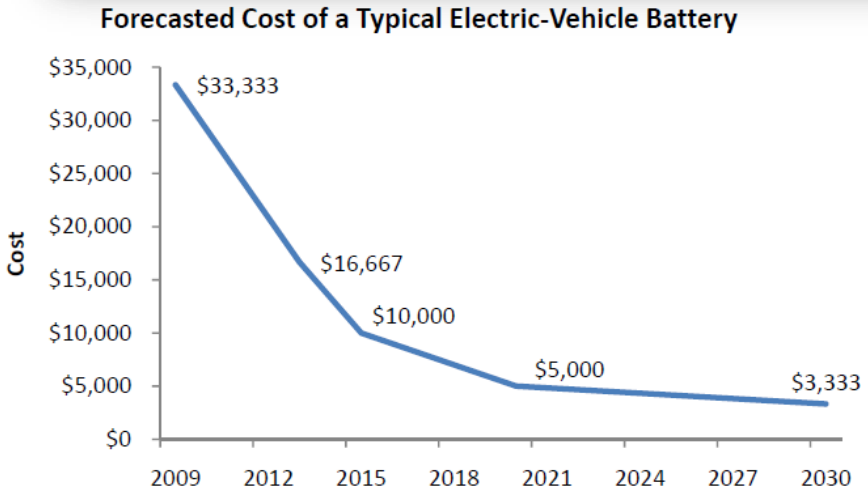
Sources:
Yilmaz, M., Krein, P.T., 2013, Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles, IEEE Transactions on Power Electronics 28 (5), pp. 2151-2169
Ajuntament de Barcelona, Use electric vehicles - Practical guide on electric mobility, http://w41.bcn.cat/downloads/use-elecric-vehicles.pdf

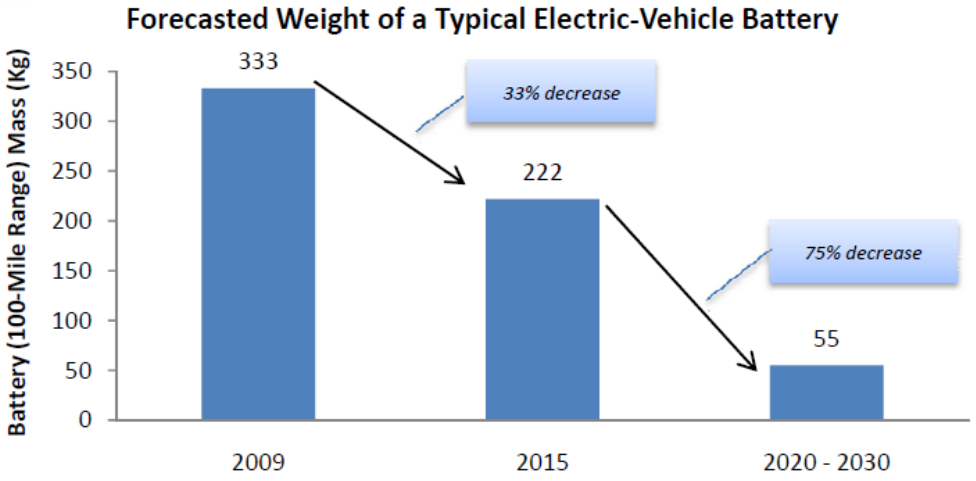
Technologies, cost and weight of EV batteries



"*Every gram of weight we can take out of the car itself would be put back into additional battery capacity.*"

Professor Herbert Kohler
Daimler's head of future mobility

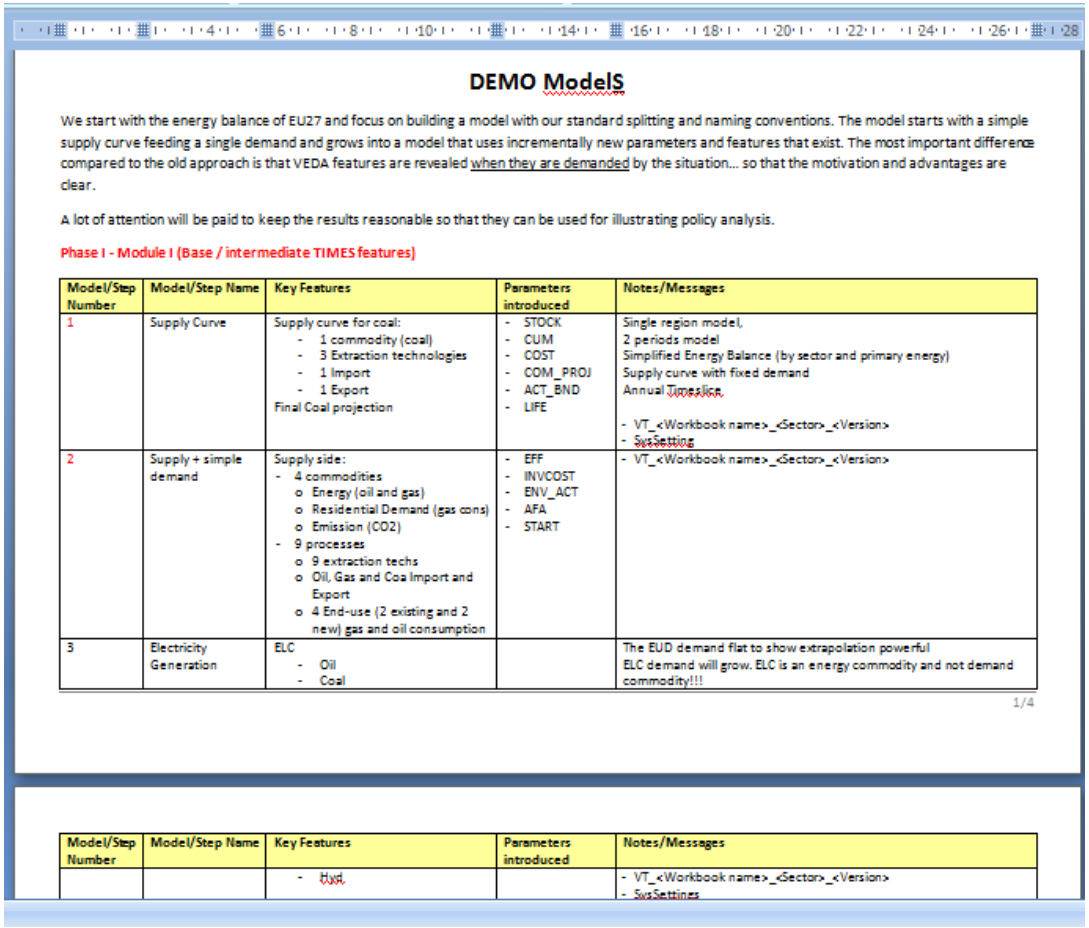




Sources:
Roland Berger Strategy Consultants, 2009,Powertrain 2020 – The Future Drives Electric
Electric & Hybrid Vehicle Technology International, July 2011
DEPARTMENT OF ENERGY, 2010, THE RECOVERY ACT: TRANSFORMING AMERICA'S TRANSPORTATION SECTOR BATTERIES AND ELECTRIC VEHICLES

TIMES demo models

- Step-by-step approach:
  - Supply curve
  - Supply + simple demand
  - Electricity generation
  - Electricity sophistication
  - Multi-regional approach
  - …



DEMO ModelS

We start with the energy balance of EU27 and focus on building a model with our standard splitting and naming conventions. The model starts with a simple supply curve feeding a single demand and grows into a model that uses incrementally new parameters and features that exist. The most important difference compared to the old approach is that VEDA features are revealed when they are demanded by the situation… so that the motivation and advantages are clear.

A lot of attention will be paid to keep the results reasonable so that they can be used for illustrating policy analysis.

Phase I - Module I (Base / intermediate TIMES features)

Model/Step Number	Model/Step Name	Key Features	Parameters introduced	Notes/Messages
1	Supply Curve	Supply curve for coal: - 1 commodity (coal) - 3 Extraction technologies - 1 Import - 1 Export Final Coal projection	- STOCK - CUM - COST - COM_PROJ - ACT_BND - LIFE	Single region model, 2 periods model Simplified Energy Balance (by sector and primary energy) Supply curve with fixed demand Annual Timeslice - VT_<Workbook name>_<Sector>_<Version> - SysSetting
2	Supply + simple demand	Supply side: - 4 commodities o Energy (oil and gas) o Residential Demand (gas cons) o Emission (CO2) - 9 processes o 9 extraction techs o Oil, Gas and Coal Import and Export o 4 End-use (2 existing and 2 new) gas and oil consumption	- EFF - INVCOST - ENV_ACT - AFA - START	- VT_<Workbook name>_<Sector>_<Version>
3	Electricity Generation	ELC - Oil - Coal		The EUD demand flat to show extrapolation powerful ELC demand will grow. ELC is an energy commodity and not demand commodity!!!

1/4

Model/Step Number	Model/Step Name	Key Features	Parameters introduced	Notes/Messages
		- Hyd.		- VT_<Workbook name>_<Sector>_<Version> - SysSettings

Source:
Technical-economic modelling with the TIMES model generator: Training course on VEDA-TIMES, Cape Town, June 2012

Existing TIMES demo model for transport

~FI_Comm

Csets	Region	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
*Commodity Set Membership	Region Name	Commodity Name	Commodity Description	Unit	Sense of the Balance EQN.	Timeslice Level	Peak Monitoring	Electricity Indicator
DEM		DTD1	Demand Transport Sector - Demand 1	PJ				
ENV		TRACO2	Transport Carbon dioxide	kt				

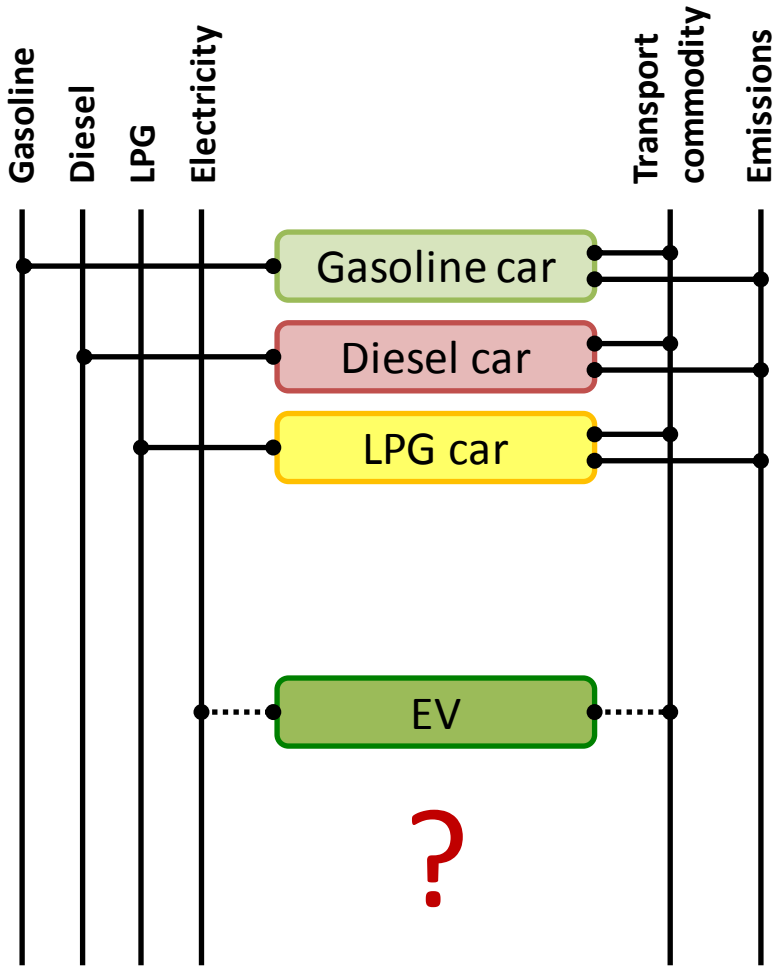
~FI_Process

Sets	Region	TechName	TechDesc	Tact	Tcap	Tslvl	PrimaryCG	Vintage
*Process Set Membership	Region Name	Technology Name	Technology Description	Activity Unit	Capacity Unit	TimeSlice level of Process Activity	Primary Commodity Group	Vintage Tracking
DMD		TOTEOIL	Demand Technologies Transport Sector - Existing Demand 1 - Crude oil and Petroleum Products	PJ	PJa			
		TOTNOIL	Demand Technologies Transport Sector - New Demand 1 - Crude oil and Petroleum Products	PJ	PJa			

~FI_T

TechName	Comm-IN	Comm-OUT	STOCK	EFF	AFA	INVCOST	FIXOM	LIFE	START	ENV_ACT
*Technology Name	Input Commodity	Output Commodity	Existing Installed Capacity	Efficiency	Utilisation Factor	Invesctment Cost	Fixed O&M Cost	Remaining Lifetime		Activity Emission Coefficient
*Units			PJa			M€/PJ	M€/PJa	Years		kt
TOTEOIL	TRAOIL	DTD1	16666	1.00	0.90	8	0.16	15		
		TRACO2								65
TOTNOIL	TRAOIL	DTD1		1.10	0.90	10	0.20	15	2006	
		TRACO2								65

Considerations for modeling of EVs



Part of Reference Energy System (RES)

(cumulative)	
100%	Fuel in 'tank' - gasoline
- 62%	Engine losses due to heat
- 17%	Standby / Idle losses
- 6%	Driveline losses
= 15%	**Tank to Wheel Efficiency**

low		high	
100%	to	100%	Fuel in 'tank' - electricity
x 99%	to	99%	Battery charge / discharge efficiency
x 90%	to	99%	Voltage Controller (electronic throttle)
x 80%	to	88%	Electric motor uses power
x 94%	to	94%	Driveline (adjusted from cumulative loss)
= 67%	**to**	**81%**	**Tank to Wheel Efficiency**

Source:
http://www.afteroilev.com/Pub/EFF_Tank_to_Wheel.pdf
http://www.bazaardesigns.com/

Existing models for EVs from KanOrs-EMR model library (2009)

- Demand template

Commodities

~FI_Comm

Csets	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
*Commodity Set Membership	Commodity Name	Commodity Description	Unit	Sense of the Balance EQN.	Timeslice Level	Peak Monitoring	Electricity Indicator
DEM	Heating	Heating Demand	PJ		DAYNITE		
	Cooling	Cooling Demand	PJ		DAYNITE		
	CarTravel	Travel By Car	PJ		DAYNITE		

- SubRES

Night storage device

~FI_Process

Sets	TechName	TechDesc	Tact	Tcap	TsIvl	PrimaryCG	Vintage
\I: Process Set Membership	Technology Name	Technology Description	Activity Unit	Capacity Unit	TimeSlice Level of oprn	Primary CommGrp	Vintage Tracking
DMD,NST	Car_ELC	Electric CAR - NST version	PJ	PJ-Yr	DAYNITE		

~FI_T

TechName	Comm-IN	TimeSlice	Comm-OUT	START	NSTTS	Life	INVCOST	STG_EFF	FLO_MARK ~CarTravel ~UP	FLO_MARK ~CarTravel ~UP~0	FIXOM	VAROM
*Technology Name	Input Commodity	TimeSlice(s)	Output Commodity	Starting Year	Charging TimeSlices	Lifetime of Process	Investment Cost	Storage Efficiency	Max Market Share	Mkt Share Extrapolate	Fixed O&M Cost	Variable O&M Cost
Car_ELC	ELC		CarTravel	2020		15	50	0.6	0.5	3		
		SN,FN,WN,RN			1							

Charging timeslices

Source:
Amit Kanudia, VEDA-FE: MODEL LIBRARY: NIGHT STORAGE DEVICES, Jun 30, 2009, http://support.kanors-emr.org/

Existing models for EVs from KanOrs-EMR / VEDA forum (2010)

Demand in million passenger-km

Commodities - Transport

~FI_Comm

Csets	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
DEM	CAR_LD	Long-Distance Car Travel	MPKms		ANNUAL		
	CAR_SD	Short-Distance Car Travel	MPKms		ANNUAL		
	TRA	Other Transport Demand	PJ		ANNUAL		
NRG	OILGSL	Gasoline					
	ELC	Electricity			DAYNITE	WP	ELC
ENV	TRACO2N	CO2 Emission - Transport	kT				
	GHG	GHG Emissions	Mt				
DEM	TTL	Passenger Train	MPKms				

~FI_Process

Sets	TechName	TechDesc	Tact	Tcap	Tslvl	PrimaryC	Vintage
DMD	TTLRELC100	Train.Light.Railcar.ELC.00.Base-year.	MVKms	000 units		DEMO	NO
DMD	CARELC000	ELC Car - dual mode - with LPG heater	MVKms	000units			YES
DMD	CARGSL00	Gasoline Car - Dual mode	MVKms	000units			YES
DMD	TRATEC00	TRA.Other Transport.00.	PJ	PJa			NO

Different efficiency for short/long distance demand

Existing Cars ~FI_T

TechName	TechDesc	Comm-IN	Comm-IN-A	Comm-OUT	CEFF	Input	Cap2Act	ACTFLO~DEMO	AF	Life
				*	MKms/PJ		stock/demand	Passenger/Car	Max Ann Km	Years
CARGSL00	Gasoline Car - Dual mode	OILGSL					0.001	1.5	20000	20
				CAR_LD	1.2					
				CAR_SD	0.9					
CARELC000	ELC Car - dual mode - with LPG heater	ELC					0.001	1.5	20000	20
				CAR_LD	2.0					
				CAR_SD	1.8					
			OILLPG			0.01				

Source:
Antti Lehtila, Topic: ELC Car as night storage technology, Jun 09, 2010, http://www.kanors-emr.org/VedaSupport/forum/uploads/30/demoplugin.zip

Existing models for plug-in hybrid EV from KanOrs-EMR / VEDA forum (2010)

- SubRES

~FI_Comm

Csets	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
FIN	G-ELCSEAS	ELC By Season		N	SEASON		

~FI_Process

Sets	TechName	TechDesc	Tact	Tcap	Tslvl	PrimaryC	Vintage
DMD	CARELC04	ELC Car - dual mode - with LPG heater - NEW	MVKms	000units			NO
DMD	CARGSL05	Gasoline Car - Dual mode - NEW	MVKms	000units			NO
DMD	TTLRELC101	New Train	MVKms	000units			NO
DMD,NST	CARPLUG05	ELC Car Plug-In Hydro	MVKms	000units			NO

~FI_T

TechName	*TechDesc	Comm-IN	Comm-IN-A	Comm-OUT	CommGrp	START	CEFF	Input	Cap2Act	ACTFLO~D	AF	Life	FIXOM	AFAC	FLO_MARK~UP	FLO_SHAR~G-ELCSEAS
*				*			MKms/PJ		stock/demand	Passenger /Car	Max Ann Km	Years	kEur/Unit per			
CARGSL05	Gasoline Car - Dual mode - NEW	OILGSL				2001.0			0.001	1.5	20000.0	20.0				
				CAR_LD			0.9									
				CAR_SD			0.6							0.8		
*																
CARELC04	ELC Car - dual mode - with LPG heater - NEW	ELC				2001.0			0.001	1.5	20000.0	20.0				
				CAR_LD			2.0								0.2	
				CAR_SD			1.9							0.8	0.3	
			OILLPG					0.0								
TTLRELC101	New Train	ELC				2001.0	24.0			27.0	31437.0					
CARPLUG05	ELC Car Plug-In Hydro	ELC			NRG	2001.0	2.0		0.001	1.5	20000.0	20.0				0.55
		OILGSL					0.7									
				CAR_LD			1.0								0.4	
				CAR_SD			0.8							0.8	0.5	

Plug-in hybrid EV: Two types of fuel

Source:
Antti Lehtila, Topic: ELC Car as night storage technology, Jun 09, 2010, http://www.kanors-emr.org/VedaSupport/forum/uploads/30/demoplugin.zip

Existing models for plug-in EV from KanOrs-EMR / VEDA forum (2012)

Demand - five demands for the five illustrative technology alternatives

~FI_Comm

Csets	CommNa	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
DEM	CARpkm1-D	Car Demand 1 - DAYNITE level	MPKms		DAYNITE		
DEM	CARpkm2-D	Car Demand 2 - DAYNITE level	MPKms		DAYNITE		
DEM	CARpkm1-A	Car Demand 1 - ANNUAL level	MPKms		ANNUAL		
DEM	CARpkm2-A	Car Demand 2 - ANNUAL level	MPKms		ANNUAL		
DEM	CARpkm3-A	Car Demand 3 - ANNUAL level	MPKms		ANNUAL		
NRG	ELC	Electricity	PJ		DAYNITE	WP	ELC
NRG	GSL	OILGSLASDA	PJ				
FIN	G-ELCSEA	Seasonal electricity	PJ	N	SEASON		

~FI_T:COM_FR

CommName	RD	RN	RP	SD	SN	SP	WD	WN	WP	FD	FN	FP
CARpkm1-D	0.1	0	0.15	0.11	0	0.14	0.09	0	0.16	0.13	0	0.12
CARpkm2-D	0.1	0	0.15	0.11	0	0.14	0.09	0	0.16	0.13	0	0.12
CARpkm1-A	0.1	0	0.15	0.11	0	0.14	0.09	0	0.16	0.13	0	0.12
CARpkm2-A	0.1	0	0.15	0.11	0	0.14	0.09	0	0.16	0.13	0	0.12
CARpkm3-A	0.1	0	0.15	0.11	0	0.14	0.09	0	0.16	0.13	0	0.12

Introduction of load curves

~FI_Process

Sets	TechName	TechDesc	Tact	Tcap	TsIvl	PrimaryC(	Vintage
IMP	IMPELC	Elc import	PJ		DAYNITE		NO
IMP	IMPGSL	GSL import	PJ				NO
DMD,NST	NSTCAR-DD	NSTCAR technology, DAYNITE-DAYNITE	MVKms	000units	DAYNITE		NO
DMD,STG	STGCAR-DD	STGCAR technology, DAYNITE-DAYNITE	MVKms	000units	DAYNITE	G-CAR2EL	NO
DMD,NST	NSTCAR-DA	NSTCAR technology, DAYNITE-ANNUAL	MVKms	000units	DAYNITE		NO
DMD,NST	STDCAR-DA	STDCAR technology, ANNUAL-ANNUAL	MVKms	000units	ANNUAL		NO
DMD,NST	STDCAR+DA	STDCAR technology, ANNUAL+ANNUAL	MVKms	000units	ANNUAL		NO

Car Processes - five alternatives, of which the first four are equivalent

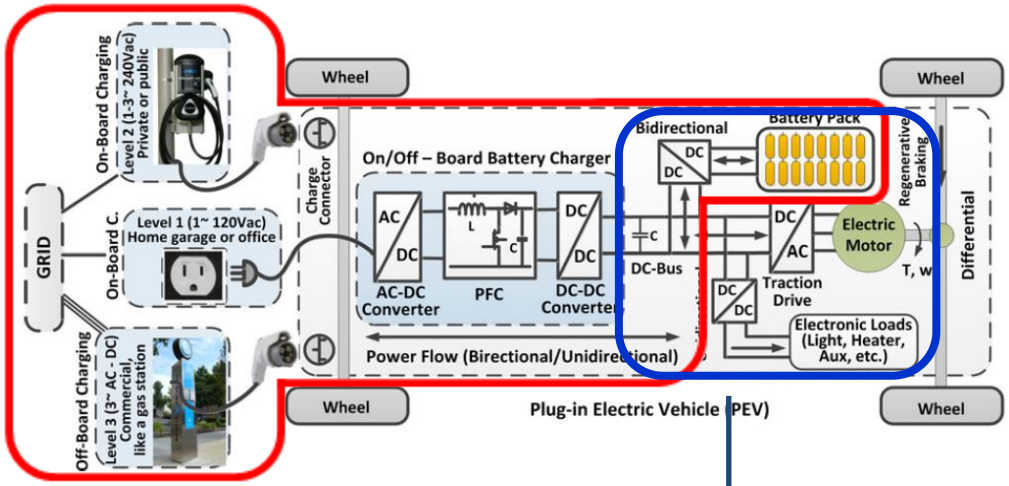
~FI_T

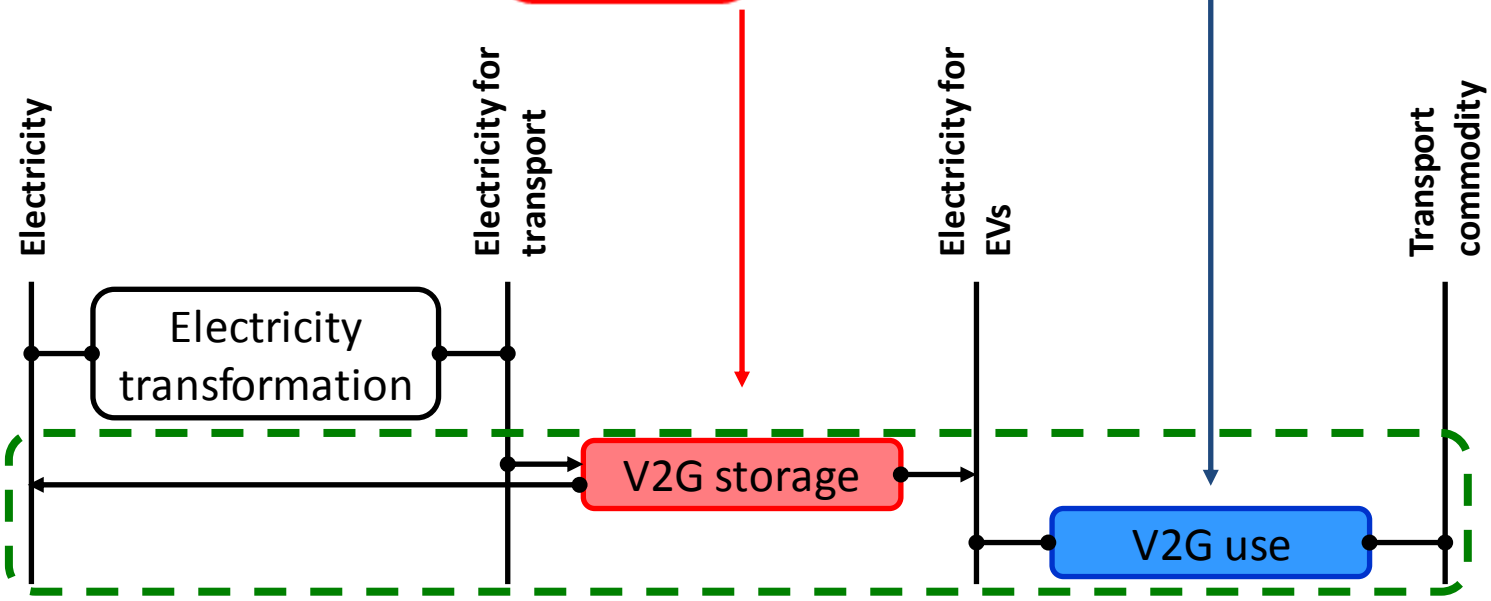
TechName	*TechDesc	Comm-IN	Comm-IN-A	Comm-OUT	CommGrp	\I: CEFF	CEFF	Cap2Act	ACTFLO	NCAP_AFC ~ANNUAL	NCAP_AFC~DAYNITE	AFA	AF	Life	INVCOST	FLO_SHAR ~UP~G-ELCSEAS
*				*		MKms/PJ		stock/demand	Passenger/Car	Max Ann Km	Max Ann Km	Max Ann Km	Max Ann Km	Years		
NSTCAR-DD	NSTCAR technology, DAYNITE-DAYNITE	ELC				3		0.001	0.3333			1	2	15	1	
		GSL				0.7			1.4286							
				CARpkm1-D					1.5000	20000	20000					
STGCAR-DD	STGCAR technology, DAYNITE-DAYNITE	ELC				3		0.001	0.3333			1	2	15	1	
		GSL				0.7			1.4286							
				CARpkm2-D					1.5000	20000	20000					
NSTCAR-DA	NSTCAR technology, DAYNITE-ANNUAL	ELC				3		0.001	0.3333			1	2	15	1	
		GSL				0.7			1.4286							
				CARpkm1-A					1.5000	20000	20000					
STDCAR-DA	STDCAR technology, ANNUAL-ANNUAL	ELC					3	0.001				20000		15	1	
		GSL					0.7									
				CARpkm2-A					1.5000							
STDCAR+DA	STDCAR technology, ANNUAL-ANNUAL	ELC			NRG		3	0.001				20000		15	1	0.6
		GSL					0.7									
				CARpkm3-A					1.5000							

Source:
Antti Lehtila, Topic: ELC Car as night storage technology, Mar 30, 2012, http://www.kanors-emr.org/VedaSupport/forum/uploads/30/TestPlugin.zip

Representation of a vehicle-to-grid (V2G) car

Vehicle-to-grid approach





V2G model: Fuel and demand commodities

- Fuel sector (*):

~FI_Comm

Csets	Region	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
*Commodity Set Membership	Region Name	Commodity Name	Commodity Description	Unit	Sense of the Balance EQN.	Timeslice Level	Peak Monitoring	Electricity Indicator
NRG		TRAELC	Transport Electricity	PJ		DAYNITE		
		TRAELCV2G	Transport Electricity for V2G cars	PJ				

~FI_T

TechName	Comm-IN	Comm-OUT	STOCK	EFF	LIFE
*Technology Name	Input Commodity	Output Commodity	Existing Installed Capacity	Efficiency	Remaining Lifetime
*Units			PJa		Years
TRAEELC	ELC	TRAELC	269	1.00	50
TRANELC	ELC	TRAELC		1.00	50

~FI_Process

Sets	Region	TechName	TechDesc	Tact	Tcap	Tslvl	PrimaryCG	Vintage
*Process Set Membership	Region Name	Technology Name	Technology Description	Activity Unit	Capacity Unit	TimeSlice level of Process Activity	Primary Commodity Group	Vintage Tracking
PRE		TRAEELC	Sector Fuel Existing Transport Sector- Electricity	PJ	PJa			
		TRANELC	Sector Fuel New Transport Sector- Electricity	PJ	PJa			

- Transport sector (*):

~FI_Comm

Csets	Region	CommName	CommDesc	Unit	LimType	CTSLvl	PeakTS	Ctype
*Commodity Set Membership	Region Name	Commodity Name	Commodity Description	Unit	Sense of the Balance EQN.	Timeslice Level	Peak Monitoring	Electricity Indicator
DEM		DTD2	Demand Transport Sector - Demand 2	Million_Pkm		DAYNITE		

- Demand and load curve (*):

~FI_T

Attribute	CommName	2005
*	Demand Commodity Name	Demand Value
*Units		Million_Pkm
Demand	DTD2	4524200

Units in Million_Pkm

~FI_T

Attribute	CommName	Timeslices	2005
*	Demand Commodity Name		
*Units			
COM_FR	DTD2	SD	0.3
COM_FR	DTD2	SN	0.1
COM_FR	DTD2	WD	0.4
COM_FR	DTD2	WN	0.2

*Showing additions only

V2G model: Processes and user constraint

- Transport sector (*):

~FI_Process

Sets	Region	TechName	TechDesc	Tact	Tcap	TsIvl	PrimaryCG	Vintage
*Process Set Membership	Region Name	Technology Name	Technology Description	Activity Unit	Capacity Unit	TimeSlice level of Process Activity	Primary Commodity Group	Vintage Tracking
DMD		TOTEOIL00	Demand Technologies Transport Sector - Existing Demand 2 - Crude oil and Petroleum Products	MVKms	000_units			
		TOTNOIL00	Demand Technologies Transport Sector - New Demand 2 - Crude oil and Petroleum Products	MVKms	000_units			
		TOTNELCV2Guse01	Demand Technologies Transport Sector - New Demand 2 - EV use Electricity	MVKms	000_units			
DMD,NST		TOTNELCV2Gstorage01	Demand Technologies Transport Sector - New Demand 2 - EV storage Electricity	PJ	PJa	DAYNITE		

~FI_T

TechName	Comm-IN	Comm-OUT	STOCK	EFF	AFA	ACTFLO	Cap2Act	INVCOST	FIXOM	LIFE	START	ENV_ACT
*Technology Name	Input Commodity	Output Commodity	Existing Installed Capacity	Efficiency			stock/demand	Invesctment Cost	Fixed O&M Cost	Remaining Lifetime		Activity Emission Coefficient
*Units			000_units	MVKms/PJ	Max Ann Km	Passenger/Car		M€/000_units	M€/000_unitsa	Years		kt
TOTEOIL00	TRAOIL	DTD2	225654	412.82	15000	1.5	0.001	20	0.4	8		
		TRACO2										65
TOTNOIL00	TRAOIL	DTD2		433.47	15000	1.5	0.001	20	0.4	12	2006	
		TRACO2										65
TOTNELCV2Guse01	TRAELCEV	DTD2		1666.67	15000	1.5	0.001	23	0.46	15	2015	

~FI_T

TechName	Comm-IN	TimeSlice	Comm-OUT	STOCK	AFA	INVCOST	FIXOM	LIFE	START	ENV_ACT	NSTTS	STG_EFF
*Technology Name	Input Commodity	TimeSlice(s)	Output Commodity	Existing Installed Capacity	Utilisation Factor	Invesctment Cost	Fixed O&M Cost	Remaining Lifetime		Activity Emission Coefficient	Charging TimeSlices	Storage Efficiency
*Units				PJa		M€/PJ	M€/PJa	Years		kt		
TOTNELCV2Gstorage01	TRAELC	SN,WN	TRAELCV2GELC					14	2015		1	0.98

- User constraint: Battery capacity corresponding to capacity unit of cars

UC_N	Pset_Set	Pset_PN	Pset_CI	Pset_CO	UC_ATTR	Year	~UC_T LimType	UC_CAP	UC_RHSRTS~0	UC_Desc
UC_EVs_equal_to_EV_batteries		TOTNELCV2Guse01				2005,2020	FX	-0.108	2	
		TOTNELCV2Gstorage01				2005,2020		1000		

*Showing additions only

Timeslices

- Timeslice resolution in existing models

Model	Timeslice per level			Total number of timeslices
	Season	Weekly	DayNite	
DEMO	S W		D N	4
PET	R S F W		D N P	12
TIMES-DK	R S F W	WD NW	A D C B	32

- EV charging options vs Charging time vs Number of timeslices
- Increasing the timeslice resolution in demo models can serve as a first step towards understanding the potential role of EVs

Conclusion

Technologies \ Regional level	World	Europe	Country	County/Region	City	Industry/ Campus
Electric vehicles						
…						
Distributed small-scale electricity						
…						
Large-scale electricity						

- Further development
  - Module with electric vehicle technologies
  - Update of parameters for technology characterization
  - Preliminary results for policy analysis
- Testing of new technologies requires definition of “regions”